BRS "EAST" Search

L Number	Hits	Search Text	DB	Time stamp
1	676	60/226.1.ccls.	USPAT; US-PGPUB; EPO; JPO; DERWENT	2003/07/02 09:38
2	57697	(starter or APU or (auxiliary adj power adj unit))	USPAT; US-PGPUB; EPO; JPO; DERWENT	2003/07/02 09:39
3	21	60/226.1.ccls. and ((starter or APU or (auxiliary adj power adj unit)))	USPAT; US-PGPUB; EPO; JPO; DERWENT	2003/07/02 09:40

United States Patent [19]

Barchenko

[11] **4,149,374**

[45] **Apr. 17, 1979**

[54] **JET PROPULSION ENGINE ASSEMBLY FOR AIRCRAFT**

[76] Inventor: **Mark R. Barchenko**, 7 Belair Ter., Wayne, N.J. 07470

[21] Appl. No.: **818,422**

[22] Filed: **Jul. 25, 1977**

[51] **Int. Cl.**[2] **F02K 3/12**

[52] **U.S. Cl.** **60/225**; 60/39.15

[58] **Field of Search** .... 60/224, 225, 226 R, 60/39.15

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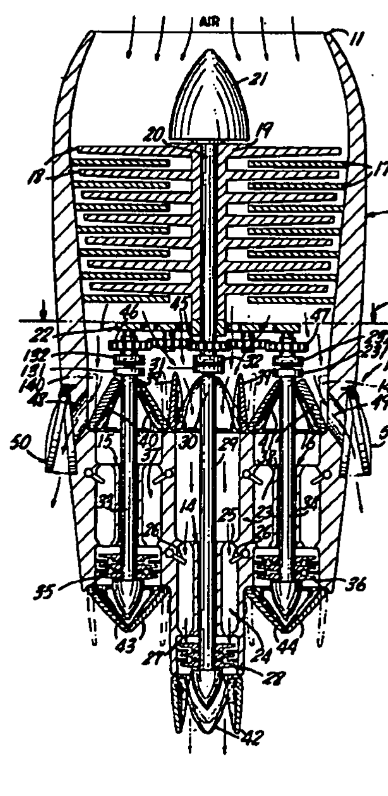
Primary Examiner—Robert E. Garrett

Attorney, Agent, or Firm—Watson, Leavenworth, Kelton & Taggart

[57] **ABSTRACT**

A jet propulsion engine assembly for aircraft embodying a longitudinal tubular pod or nacelle housing having an open air intake nose. This assembly includes an axial air flow impeller supported longitudinally in the interior of and by the housing, and it has an annular array of rotary blades supported therein upon a rotatably supported, longitudinal and generally central shaft to force air from the intake nose longitudinally back toward the tail end of said housing. A central jet engine within this housing has a longitudinal drivable shaft substantially aligned with the impeller shaft and drivably connected thereto by disengageable clutching means for effecting drive of the latter from the former when the engine shaft is power driven by the central engine. A plurality of flanking jet engines also have longitudinal drivable shafts arranged within said housing substantially equally offset laterally from the central engine while being annularly spaced substantially equal radial angles apart with ther shafts also connected to the impeller shaft by independent disengageable clutching means whereby each flanking engine and the central engine may be selectively disengaged from the impeller shaft independently of the others. The space within the housing downstream of the means which connects the impeller shaft to the shafts of the plurality of jet engines is sub-divided into a plurality of separated longitudinal spaces which individually house the jet engines. Each of the jet engines has associated with its longitudinal drivable shaft upstream of this engine and downstream of the air flow impeller an individual cooperative upstream airflow door appreciably to close off airflow from the impeller back through the longitudinal housing space of this engine upon termination of combustion in the latter.

8 Claims, 5 Drawing Figures



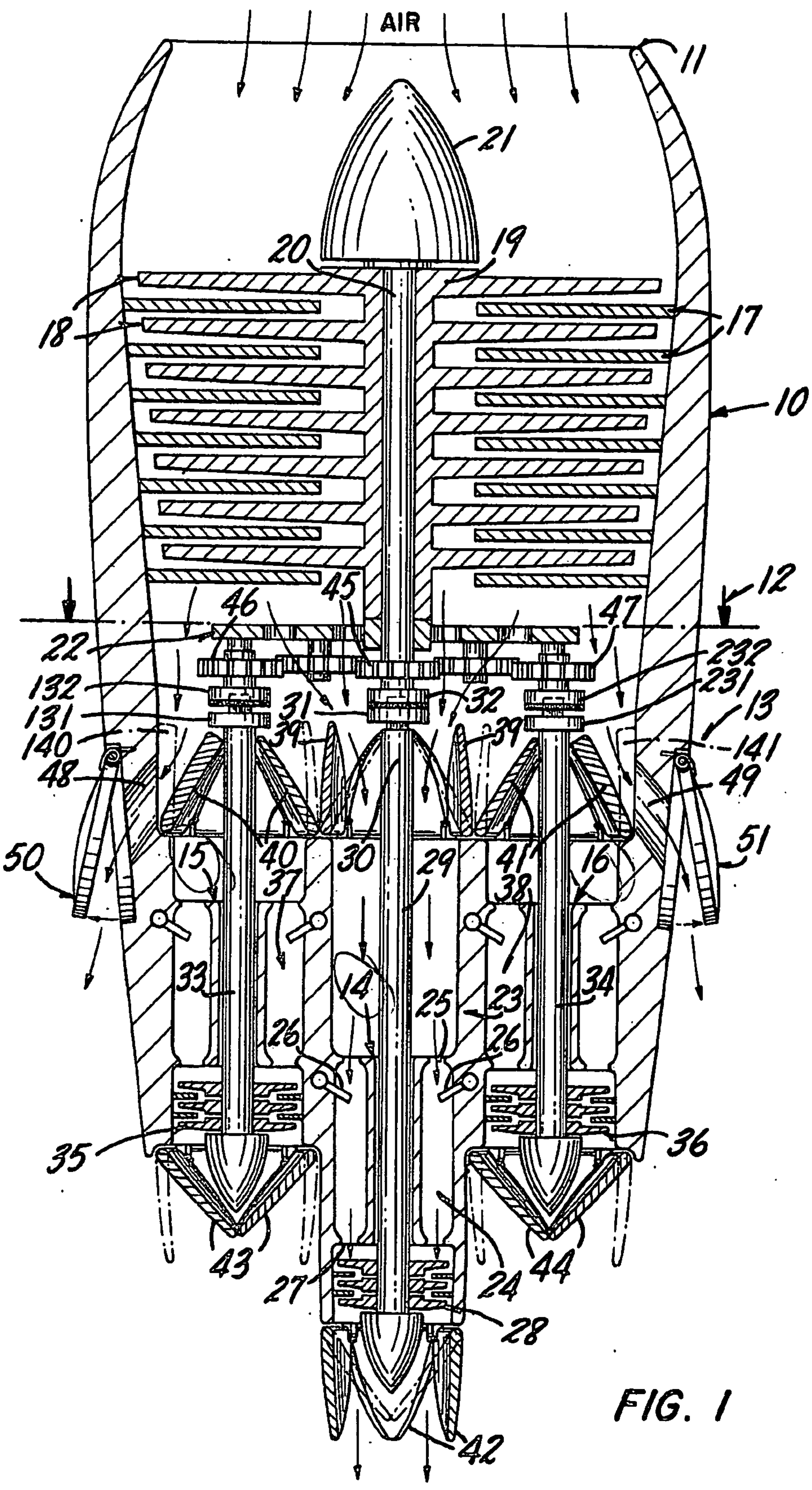

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FIG. 1

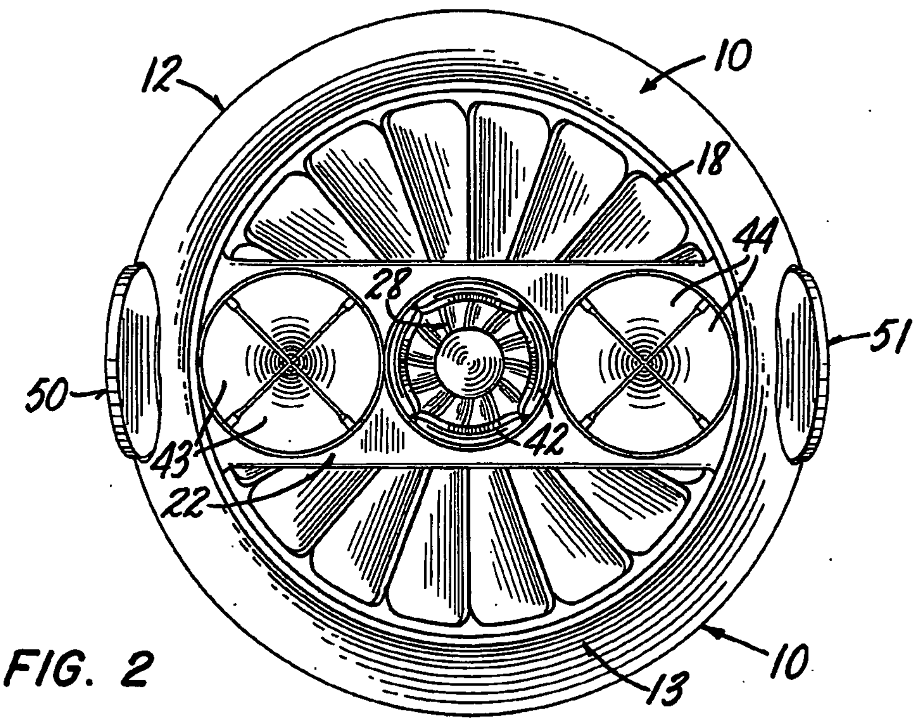
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FIG. 2

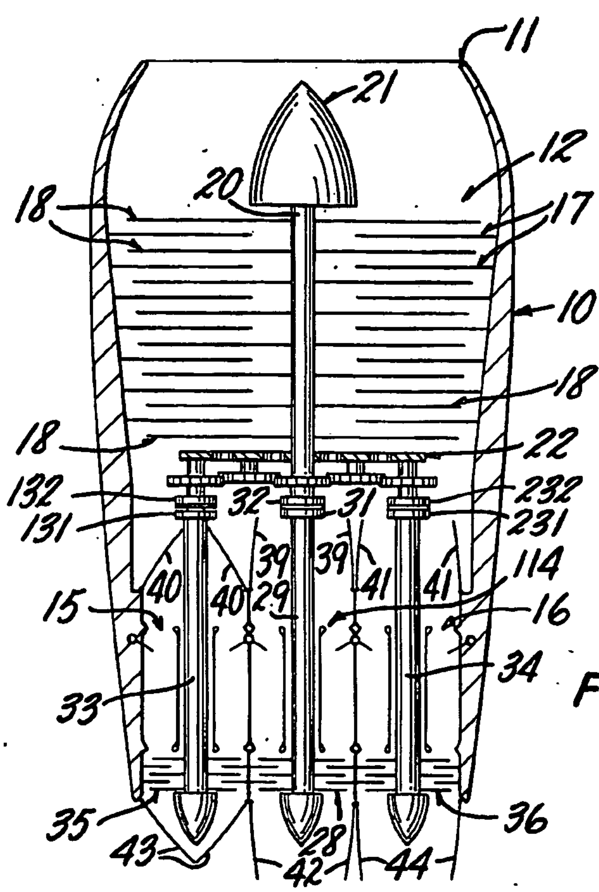
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FIG. 3

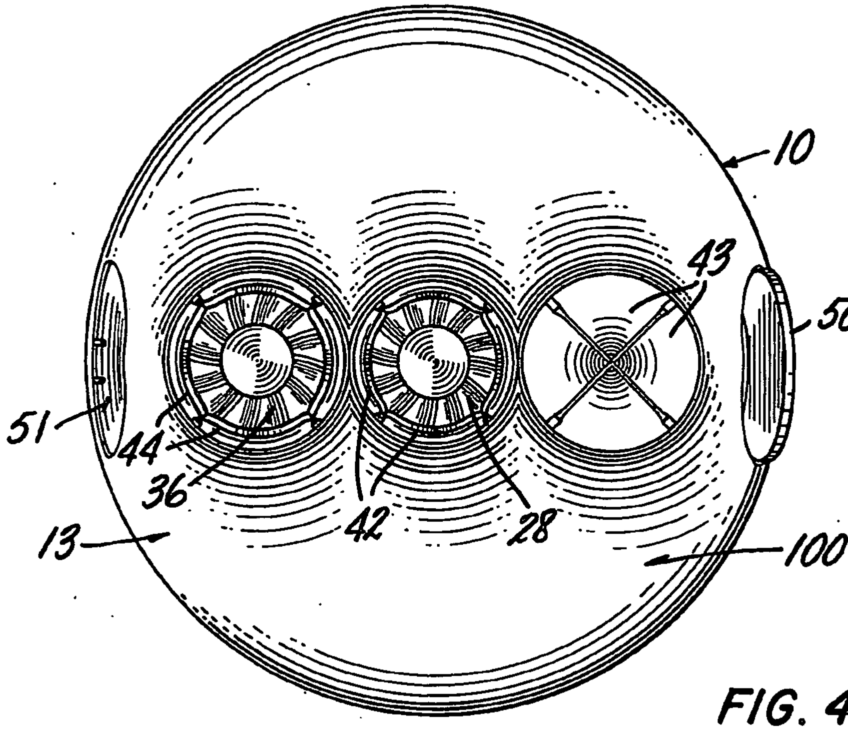

FIG. 4

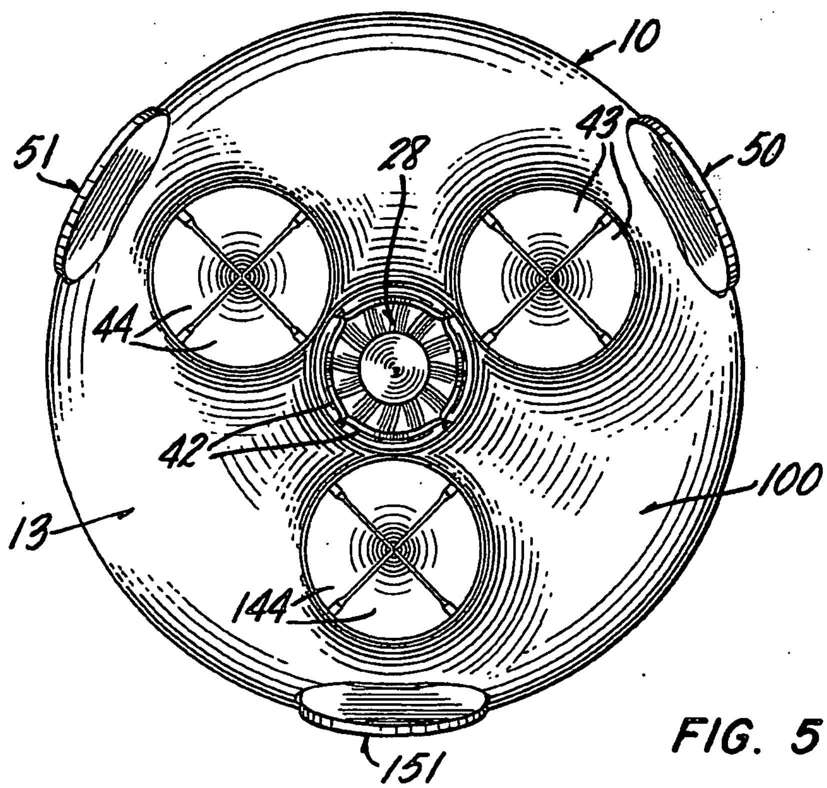

FIG. 5

JET PROPULSION ENGINE ASSEMBLY FOR AIRCRAFT

BACKGROUND AND SUMMARY

The present invention is concerned with a jet propulsion engine assembly for aircraft mounted within a longitudinal pod or nacelle housing. It is chiefly concerned with the enclosure in such housing having an open air intake nose and an openable tail end which preferably permits selective exhaust out of the latter from a plurality of operating jet propulsion engines housed therein.

In the prior art it has been proposed in the United States Griffith Pat. No. 3,153,907 of Oct. 27, 1964 to mount concentrically in a tubular outer casing a central tubular engine pod in which is clustered about the central axis of the latter a pair of diametrically spaced and longitudinally extending gas turbine engines. Longitudinal shafts of these engines are geared to a central longitudinal air impeller shaft downstream of the exhausts of the turbines of the pair of engines and within the gas flows from the latter to hazard heat injury to the gearing. These engines drive in opposite directions through such gearing a pair of coaxial fans within the tubular outer casing to force air rearward through the latter into which the engine exhaust gases flow. Such gaseous mixture is ultimately exhausted downwardly through openings in elongated zones of the bottom of the fuselage to provide some vertical lift. Accordingly, these proposals are not pertinent to the subjects matter claimed herein.

It is a general object of the present invention efficiently to embody in a longitudinal tubular housing having an open air intake nose, a typically conventional type of airflow impeller which may be of the compressor or fan blade types, or other obvious variants thereof, with the rotary blades of the impeller carried by a longitudinal central shaft driven from a central jet engine mounted within the housing having its longitudinal shaft aligned with the impeller shaft and drivably connected thereto by disengagable clutching means for drive of the impeller shaft by this engine when operating. This generic embodiment includes a plurality of flanking jet engines which respectively have drivable longitudinal shafts and are arranged annularly about the central engine at substantially equal radial angles apart with their shafts also drivably connected to the impeller shaft by independent disengagable clutching means so that each of the engines may be selectively disengaged from the impeller shaft upon inoperability of any of such engines. The drive shaft of each of the engines of this generic embodiment has associated therewith upstream of this engine and downstream of the impeller an individual cooperative upstream airflow door means so as appreciably to close off airflow from the impeller back through the housing space of this particular engine upon termination of combustion in the latter.

The jet power plants or engines proposed herein for employment in various embodiments of the present invention may be of a variety of types, e.g., turbojets, fanjets, and variations thereof. By way of example the present disclosure proposes the use of jet engines of the gas turbine type with the longitudinal shaft of each such engine being driven by its turbine.

When embodiments of the invention include the basic combinations of units or subassemblies indicated above it is important that the upstream doors of each jet engine are embodied to cooperate with the longitudinal shaft thereof for substantially closing off flow of pressurized air from the impeller back through the interior of such an engine when it becomes inoperative, such as by flame-out. However, although it may be desirable also to provide the downstream tail pipe exhaust opening of each of the engines with suitable closing doors, perhaps as a protective measure or stream lining function, this is not an essential feature.

It is desirable to provide engines of embodiments of the invention with air bleed-off systems to reduce the intake to thrust ratio when one or more of the engines is or are inoperable so that performance of the operating engines is not hampered.

Another object of the invention is to make provision for reducing the ratio of air intake into the tubular housing or nacelle in which the group of engines are mounted and operated to the thrust produced by the operating engines when one or more of the group are inoperable, so that performance of the operating engines is not undesirably hampered. In accordance with a feature of the present invention this may be accomplished satisfactorily by a selective air bleed-off system intervening the air impeller and the air intakes of the engines. Advantageously and uniquely this may be attained by incorporating with the upstream airflow door means of each of the flanking engines provision for bleeding off impeller-supplied pressurized air when the particular door means that is associated with a certain such engine that becomes inoperable is manipulated to closure of the upstream air intake of this particular engine. Such air bleeding-off means may include provision for directing such pressurized air at such door means to and out through an air escape outlet having direct communication with the atmosphere and which is operatively effective only upon closure of the upstream door means of this engine. More specifically, such certain door means may have a manipulative section which in one position closes this associated air escape outlet with simultaneous opening of the flow passage from the impeller back through the particular flanking engine, and vice versa.

An additional object of the invention is to provide advantageously such impeller-supplied air escape equipment with manipulative fairing means which will close off and cover advantageously the exterior escape outlet when the upstream airflow door means of a particular operating flanking engine is open to satisfy the air demand of this engine.

It may be desirable for some services to take advantage of the secondary thrust created by the impeller pressurized air at the rear of the tubular housing as it bypasses the flanking engines and the central engine, for supplementing the thrust of the combustion gases exiting from the tail pipes of the operating engines, such as in a fanjet type engine. The more the flanking engines which are clustered about the central engine, within the longitudinal tubular housing or nacelle, the lesser will be the flow through spaces at the open tail end of the housing. Other services may demand that such intervening spaces between the tail pipes of the engines and also between them and the nacelle housing be closed off by fairing skin of the housing which may be smoothly tapered from the open front end section back to the thrust nozzles provided by the open downstream ends of the tail pipes, such as in a turbojet type engine.

If thrust reversers are required for such an engine assembly, as may be the case for power plants of airliners, they readily may be installed and used without

undue interference with the structures embodying features of the present invention and the functions of the latter. The functions of such thrust reversers may be embodied in downstream door means which may desirably function as closing doors when desired.

Other objects of the invention will in part be obvious and will in part appear from reference to the following detailed description taken in connection with the accompanying drawings, wherein like numerals identify similar parts throughout, and in which:

FIG. 1 is an axial section of a jet propulsion engine assembly of the present invention, in which are embodied various basic features of the present invention and illustrating a single airflow impeller in the open nose section of the tubular housing thereof, with the tail section provided with a central engine axially connected to the impeller rotor through a disengaging clutch and flanked on opposite sides by somewhat similar engines geared thereto through separate disengaging clutches;

FIG. 2 is a tail end view of the jet propulsion engine assembly of FIG. 1;

FIG. 3 is a diagrammatic illustration of the assembly of FIG. 1 from which has been omitted a showing of certain air escape outlet means, with one of the three engines being shown as shut down while the other two engines remain clutched to the impeller shaft;

FIG. 4 is a tail end view of a jet propulsion engine assembly similar to that illustrated in FIG. 3, with the addition to the showing of the latter of the door means for the upstream airflow doors and escape outlets and also the addition thereto of fairing skin which closes off the tail end of the longitudinal tubular housing except for the tail end pipes of the three engines; and

FIG. 5 is a tail end view of a jet propulsion engine assembly similar to that illustrated in FIG. 4 while featuring a cluster of three flanking jet engines arranged at equal angular distances about the central jet engine with only the latter being operative.

As is illustrated in FIG. 1, with some parts indicated diagrammatically with others which are of obvious character being omitted as unnecessary, it will be seen that the embodiment of the jet propulsion engine assembly for aircraft there illustrated has a longitudinal tubular housing 10 that serves as an enclosing pod or nacelle and having an open air intake opening 11 of a nose section 12. The remaining section 13 constitutes a tail section which embodies a cluster or plurality of jet engines including a central engine 14 and a pair of flanking engines 15 and 16.

The nose section 12 of the longitudinal tubular housing 10 carries fixed therein a stator structure 17 of conventional type, if desired, with the annular array of fixed blades thereof interdigitated between the rotor blades 18 carried by a central hub 19 about an axial shaft 20, which may be equipped on its air entrance end with a conical hub nose 21. The impeller shaft 20 is suitably rotatably supported by bridge work graphically represented by a perforated bridge plate 22 which may be suitably holed through to reduce to a minimum interference with airflow back from the nose section 12 into the tail section 13.

The tail section 13 is provided in any suitable manner with fixed structure which defines a cylindrical casing 23 of the central jet engine 14, with the interior of this casing communicating rearwardly with combustion chamber means 24 provided upstream with an entrance opening 25 for the impelled pressurized air from the impeller back into the combustion chamber. In the latter are located fuel supply nozzles 26, so that upon firing of such fuel the resulting hot gases exit from such combustion chamber means through exit passage 27 for driving rotatably gas turbine 28.

The gas turbine 28 is fixed upon a rotary central shaft 29 suitably rotatably supported in bearing means and with its upstream end 30 provided with a clutch driven element 31 suitably engaged by a clutch driving element 32 which is rotatably carried by the rotary impeller shaft 20. The disengagable clutching means 31-32 may be of conventional structure known in the art and so equipped as to separate the driving element 32 from the driven element 31 as may be dictated by any remote control for discontinuing rotation of the shaft 29 and the turbine rotor 28 carried thereby. Thus the central engine 14 carries its turbine rotor 28 for drive thereof and consequential drive of the shaft 29 for rotating the impeller rotor 18 through the engaged clutch 31-32.

Flanking engines 15 and 16 may be of generally similar construction as the central engine 14 with the shafts 33 and 34 thereof respectively driving rotors 35 and 36 of similar gas turbines which will be driven when such engines are fired up by combustion of fuel in their respective chambers 37 and 38. By way of example, it has been assumed that such flanking engines 15 and 16 have been rendered inoperative such as, for example, by flame-outs, so that there is at such time no need for flow of pressurized air back from the impeller through these flanking engines. It will thus be noted that the disengagable clutching means 131–132 and 231–232 have been disengaged, such as by suitable remote control means for discontinuing the longitudinal turbine-driving shafts 33 and 34 of these flanking engines 15 and 16.

Consequently, it is no longer desired to flow pressurized air from the impeller in the upstream impeller section 12 back through the flanking engines 15 and 16. Accordingly, it is desirable to discontinue such flow into such flanking engines by manipulating to closed conditions individual cooperative upstream airflow door means 40 and 41, as shown in FIG. 1. Since the central jet engine 14 remains operative its upstream door means 39 remains open for passage down into the combustion chamber 24 of this jet engine.

Since it may be desired to provide door means at the tail ends of all three of the jet engines 14, 15, and 16, such as those proposed at 42, 43, and 44, it will be noted from FIGS. 1 and 2 that such downstream door means of the central jet engine 14 remains open for exit of the jet power from this central engine, while the downstream doors 43 and 44 of the flanking engines 15 and 16 are closed simultaneously with their upstream door means 40 and 41 upon attaining inoperative conditions of these flanking engines. It is to be understood that these now closed downstream door means 43 and 44 of the flanking jet engines 15 and 16 will be opened up simultaneously with their respective upstream door means 40 and 41. This is likewise true with respect to the upstream door means 39 of the central jet engine 14 and its downstream door means 42, which will be simultaneously opened and closed alternately as the firing conditions dictate.

It will be noted from FIG. 1 that each of the longitudinal shafts 29, 33, and 34 of the central and flanking jet engines 14, 15, and 16 are suitably connected through disengagable clutches 31–32, 131–132, and 231–232 and suitable gearing to the impeller shaft 20. For example, closed disengagable clutch 31–32 drivably connects the

driven shaft 29 of the firing central jet engine 14 to the impeller shaft 20 so that the impeller is driven by this activated central engine. The clutches 131-132 and 231-232 of the flanking engines 15 and 16 respectively have become automatically disengaged by virtue of the shut down or deactivation of the flanking jet engines 15 and 16. It will be noted that in the drive of the impeller assembly in housing section 12 the impeller shaft 20 is not only connected to the central jet engine shaft 29 through the closed clutch assembly 31-32, but also carries, fixed thereto, a suitable spur gear 45 which is meshed with suitable gear trains including spur gears 46 and 47 which are respectively connected for drive to the flanking engine shafts 33 and 34 through the clutches 131-132 and 231-232 when engaged and such flanking engines are fired. Accordingly, any one or two of the three jet engines when firing may drive the air intake impeller.

Assuming that the intake air impeller is being driven by the central jet engine 14 with the flanking jet engines 15 and 16 shut down and the upstream doors of the latter 40 and 41 closing off the entrance ends of the latter, it may be desirable to have provided and to use air escape outlets which extend laterally through the longitudinal tubular housing or nacelle shell 10 for escape of pressurized air therethrough directly to the outside atmosphere. For this purpose side air escape ducts 48 and 49 may be provided for such communication to the outside air of the pressurized air within the nacelle shell. It will be noted from FIG. 1 that when either one or both of the flanking engines 15 and 16 are shut down its or their upstream door means 40 and 41 is or are in the closed positions indicated. Thus one door shell or leaf on the outer side of each may be suitably shaped so that when it is pivotally swung to the open position, such as that indicated in broken lines at 140 and 141, they will close off the air escape outlets 48 and 49. It may also be desirable to provide the lateral air escape outlets 48 and 49 with manipulative fairing means, such as pivoted and spring-biased covers 50 and 51, so that they may be respectively or simultaneously swung to outward positions of opening of the air escape outlets 48 and 49.

The tail end view in FIG. 2 of the jet propulsion engine of FIG. 1 illustrates the rotor impeller assembly 18 is conventional form and as though the rotary blades thereof could be viewed from such rear position on opposite sides of the fixed transverse bridge 22 within the nacelle casing 100 which supports structure of the central and flanking engines 15 and 16 as well as the central engine 14 and the impeller rotor assembly. The holing through of bridge 22 shown in FIG. 1 is omitted herein as unnecessary to an understanding of its service.

In FIG. 3 it is illustrated that the end of the tail pipe of the central engine 14, which is indicated in FIG. 1 as extending downstream appreciably farther than the ends of the tail pipes of the flanking engines 15 and 16, may be foreshortened so that all three are substantially in the same transverse plane. This can be advantageous particularly if such a jet propulsion engine assembly is mounted as a pod engine mounting upon a wing of an airline or transport plane to avoid heating up such a rearwardly extending tail section of the central jet engine by the temperatures of the exhausts from the tail pipes of the flanking jet engines. Having all of the exhausts of the plural engines in the same transverse plane may make pod mounting easier.

It is proposed in FIGS. 4 and 5 that the nacelle shell be of such construction as to permit fairing skin 100 to form a continuation of the surface of the tail section 13 so as to close in the rear end of the engine assembly with exposure only of the downstream door means 42 of the central jet engine 14 and those at 43 and 44 of the flanking jet engines 15 and 16 in a smooth tapering streamlined manner. It is illustrated in FIG. 4 that the central jet engine 14 and the flanking jet engines 15 and 16 are all diametrically aligned so that these flanking jet engines are at equal angular distances apart, i.e., 180°.

It is also indicated in FIG. 5 that additional flanking engines may be provided and, in fact, may be multiplied up to a limit dictated by the space available within the longitudinal tubular housing or nacelle shell 10. Thus three flanking jet engines may be arranged about the central jet engine at substantially equal radial angles apart, such as about 120°, as is indicated in FIG. 5. The extra flanking jet engine which has downstream closing doors 144 may be similar in all respects to the flanking jet engine which has downstream closing doors 44, which in turn may be equivalent to the flanking jet engine which has downstream closing doors 43. If, as is indicated in FIG. 5, all three of the flanking jet engines are arranged annularly at substantially equal angular distances about the central jet engine that has its gas turbine 28 located centrally of the construction each preferably will have associated therewith air escape outlets that can advantageously be covered by suitable manipulative fairing covers indicated at 50, 51, and 151. As is therein indicated the downstream section 13 of the housing may be provided with fairing skin 100 similar to that indicated in FIG. 4 and described above.

An annular zone of the front end of the engine nacelle, preceding the air compressor therein, may be provided with an annular series of air intake slits, which may be rectangular with their long dimensions arranged annularly, or they may be of other suitable shapes. Each of these slit openings could be controlled by a rectangular door that automatically opens to increase the area of air intake when sudden surges of power demand occur on takeoff and landing. These slits can be closed by their doors automatically at a certain increased altitude. The opening of these doors can prevent engine stalling due to insufficient air supply upon sudden increases of power demand. These doors may have their upstream sides hingedly supported and their downstream sides dropped down into the interior nose space upon the increased demand for suction therethrough of the additionally required air. Thus, the engine assembly may be equipped with a variable geometric intake to feed larger air supply to the engines and also to reduce this supply when internal airflow stabilizes.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is the novel subjects matter defined in the following claims.

1. A jet propulsion engine assembly for aircraft embodying a longitudinal tubular housing for serving as an enclosing pod or nacelle and having an open, air intake nose, in combination with

(1) an axial airflow impeller supported longitudinally in the interior of and by said housing having an annular array of rotary blades supported therein upon a rotatably supported longitudinal and generally central shaft to force air from the intake nose longitudinally back toward the tail end of said housing;

(2) a central jet engine within said housing having a longitudinal drivable shaft substantially aligned with said impeller shaft and drivably connected thereto by disengagable clutching means for effecting drive of the latter from the former when said engine shaft is power driven by said central engine;

(3) a plurality of flanking jet engines also having longitudinal drivable shafts arranged within said housing substantially equally offset laterally from said central engine while being annularly spaced substantially equal radial angles apart with their shafts also connected to said impeller shaft by independent disengagable clutching means whereby each said flanking engine and said central engine may be selectively disengaged from said impeller shaft independently of the others;

(4) means longitudinally subdividing the space within said housing downstream of said means connecting said impeller shaft to the shafts of said plurality of jet engines into a plurality of separated longitudinal spaces which individually house said jet engines; and

(5) each of said jet engines having associated with its longitudinal drivable shaft upstream of this engine and downstream of said airflow impeller an individual cooperative upstream airflow door means appreciably to close off airflow from said impeller back through the longitudinal housing space of this engine upon termination of combustion in the latter.

2. The jet propulsion engine assembly defined in claim 1 characterized by each of said central and flanking jet engines being of the gas turbine type with its longitudinal shaft being driven by its turbine.

3. The jet propulsion engine assembly defined in claim 1 characterized by each of said jet engines having associated with its longitudinal housing space downstream door means adapted to be manipulated between airflow open and closed conditions substantially simultaneously with its upstream airflow door means.

4. The jet propulsion engine assembly defined in claim 1 characterized by said tubular housing being provided in the near vicinity of said upstream airflow door means of each of said flanking engines with an air escape outlet extending laterally therethrough to direct communication with outside air for flow of impeller air out therethrough upon closure of said upstream door means.

5. The jet propulsion engine assembly defined in claim 4 characterized by said upstream airflow door means of each of said flanking engines having a manipulative section which in one position closes the associated air escape outlet and simultaneously opens the flow passage from said impeller back through this particular flanking engine.

6. The jet propulsion engine assembly defined in claim 4 characterized by each of said lateral air escape outlets having manipulative fairing means associated therewith to cover it exteriorly when said upstream airflow door means of the flanking engine, with which said escape outlet is associated, is open with closure thereby of the escape outlet.

7. The jet propulsion engine assembly defined in claim 1 characterized by said engine assembly tubular housing having its tail end closed off by fairing skin except for the downstream ends of said jet engines with the latter communicative to the atmosphere therebehind through openings in said fairing skin.

8. The jet propulsion engine assembly defined in claim 1 characterized by the downstream exhaust ends of said plurality of longitudinal engine housing spaces located substantially in the same transverse plane effectively avoiding lateral transfer of exhaust heat from one to exhaust structure of another that may otherwise extend farther downstream from that one.

* * * * *

US005349814A

United States Patent [19]

Ciokajlo et al.

[11] Patent Number: 5,349,814

[45] Date of Patent: Sep. 27, 1994

[54] AIR-START ASSEMBLY AND METHOD

[75] Inventors: John J. Ciokajlo; Michael T. O'Brien, both of Cincinnati, Ohio

[73] Assignee: General Electric Company, Cincinnati, Ohio

[21] Appl. No.: 12,664

[22] Filed: Feb. 3, 1993

[51] Int. Cl.^{5} F02C 7/262

[52] U.S. Cl. 60/226.1; 60/39.142

[58] Field of Search 60/39.091, 39.142, 226.1, 60/39.163

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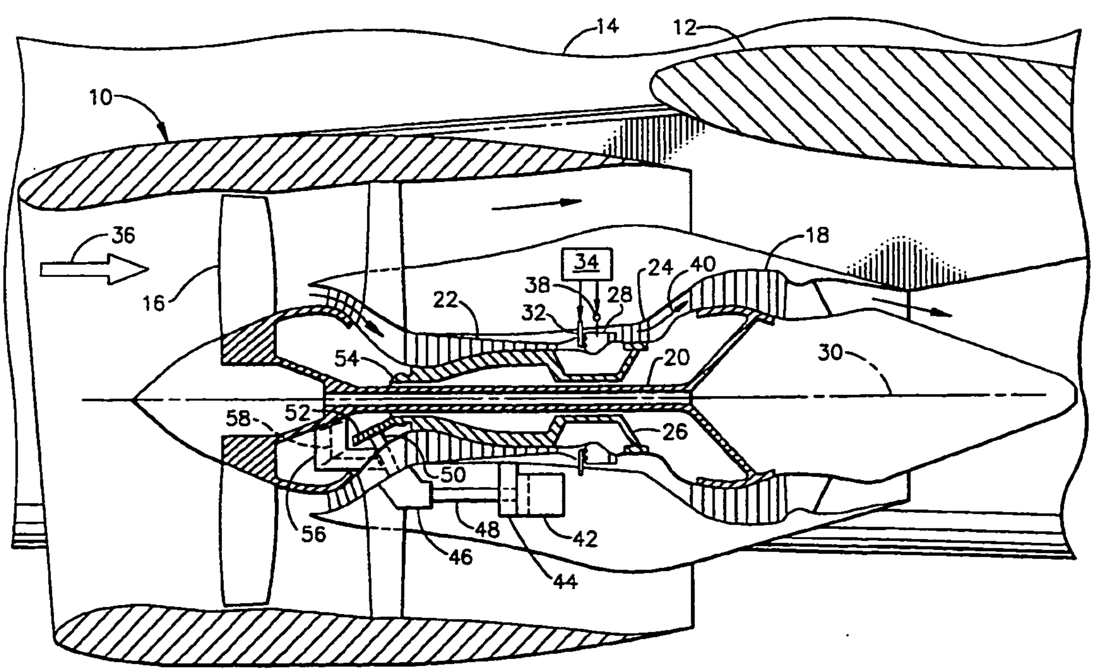
Primary Examiner—Richard A. Bertsch
Assistant Examiner—William J. Wicker
Attorney, Agent, or Firm—Jerome C. Squillaro; Nathan D. Herkamp

[57] ABSTRACT

A method and assembly are effective for air-starting an aircraft gas turbine engine having a fan powered by a low pressure turbine through a first shaft, and a compressor powered by a high pressure turbine through a second shaft disposed coaxially therewith. A gear train is selectively operatively joined between the first and second shafts by selectively engaging a first clutch for transmitting torque through the first clutch only in one direction from the first shaft to the second shaft when the fan is windmilling for driving the second shaft to allow an air-start of the gas turbine engine during flight. In a preferred embodiment, a second clutch is operatively joined to the gear train and is selectively engageable at speeds of the second shaft below a predetermined release speed, and disengageable at the release speed and above for disconnecting the air-start assembly once the engine has been started.

7 Claims, 5 Drawing Sheets



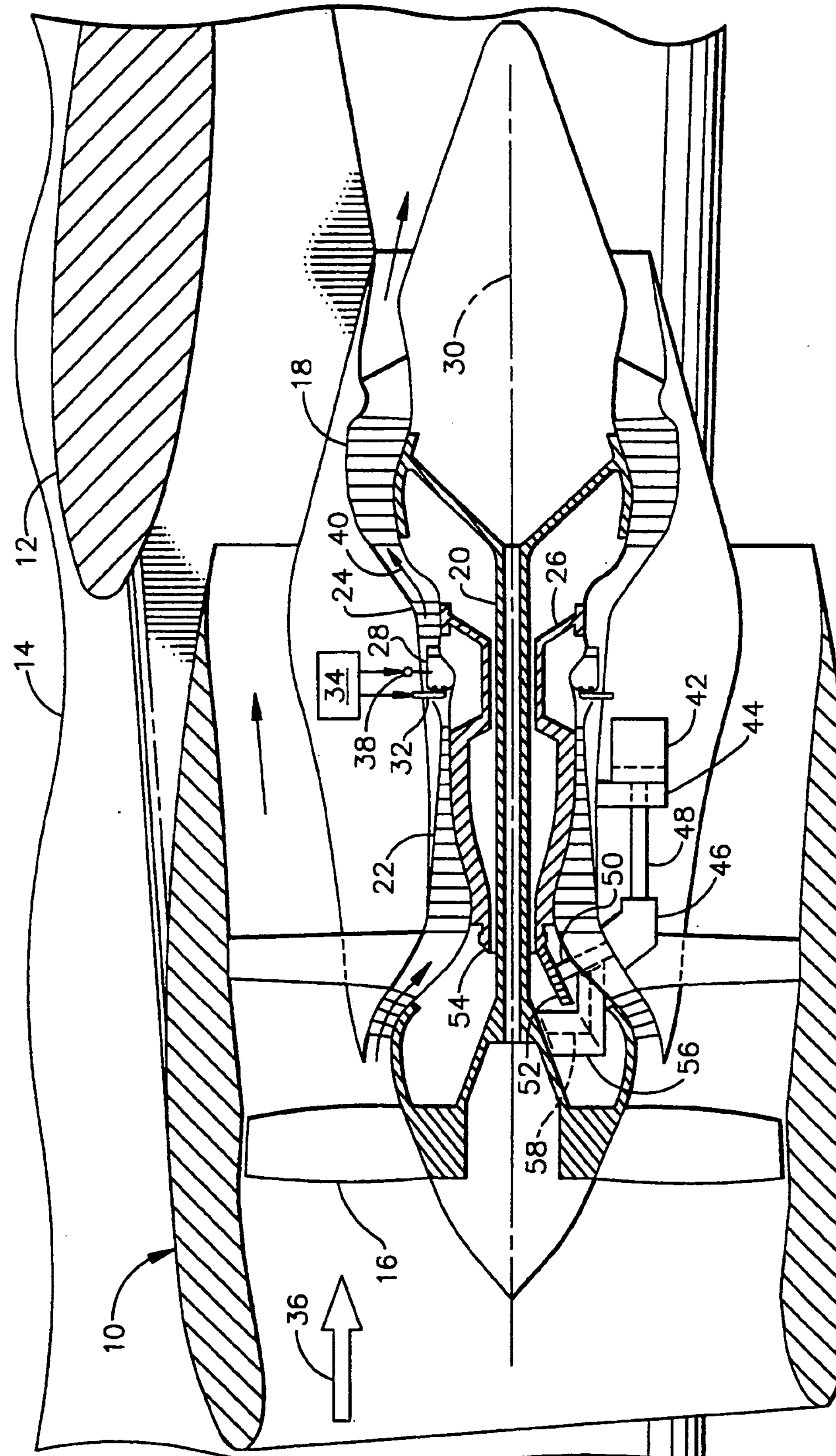

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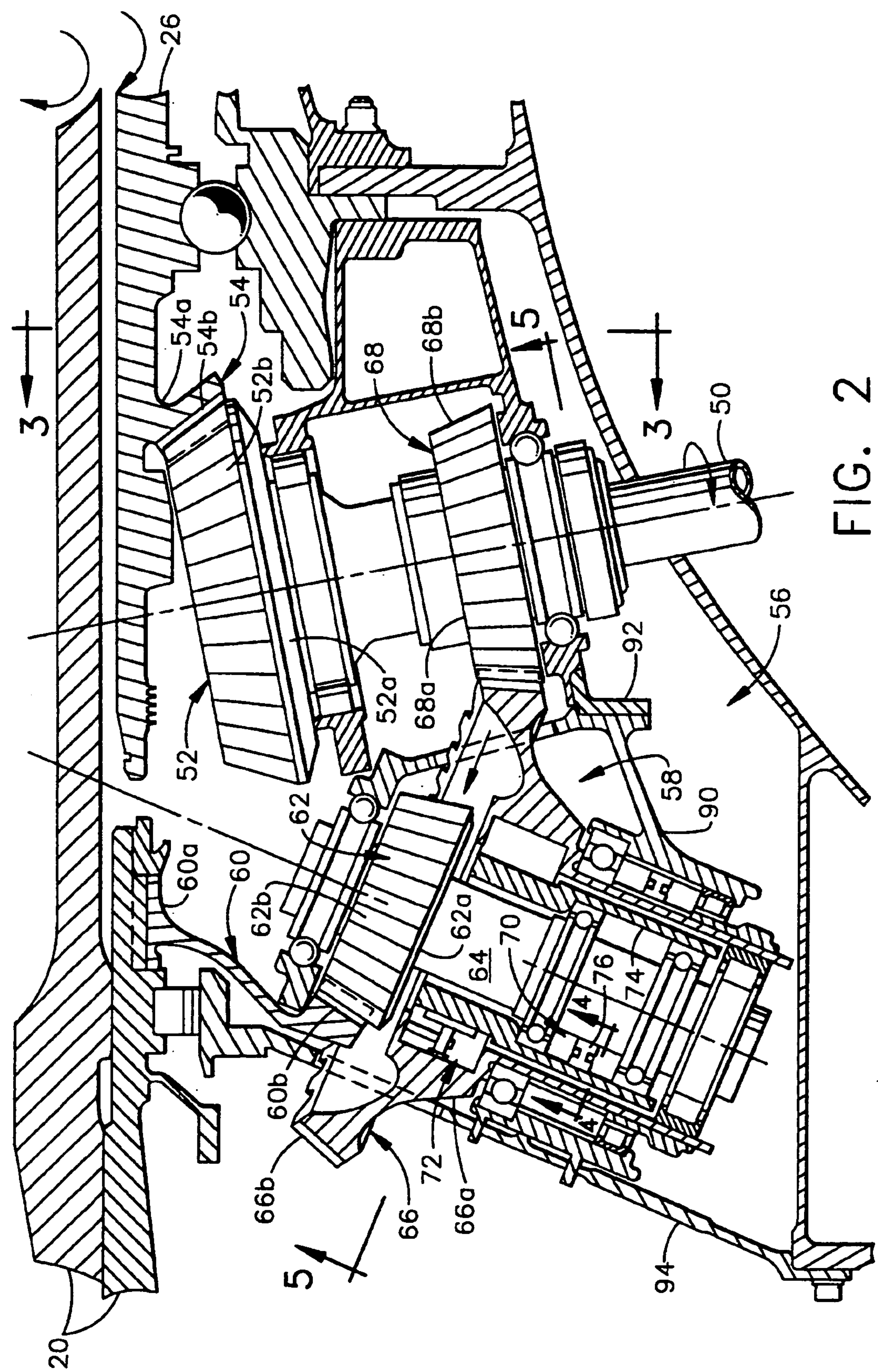
FIG. 1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94
20

FIG. 2

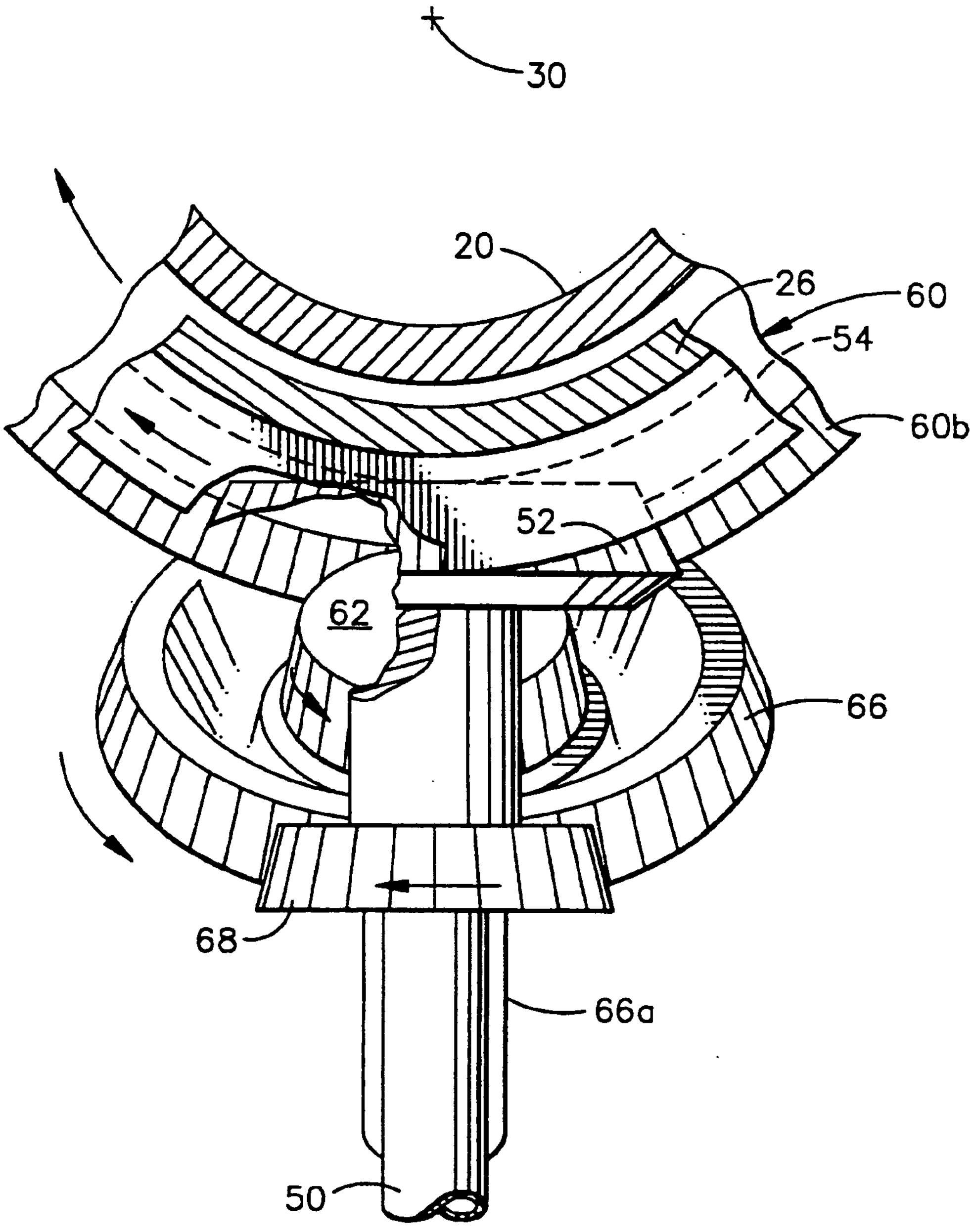

FIG. 3

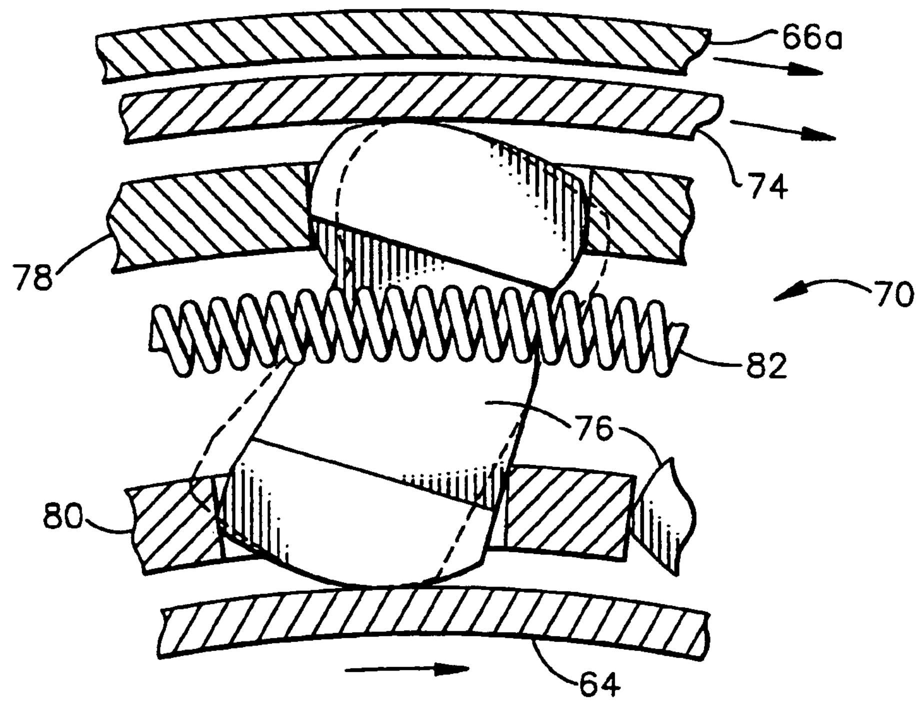

FIG. 4

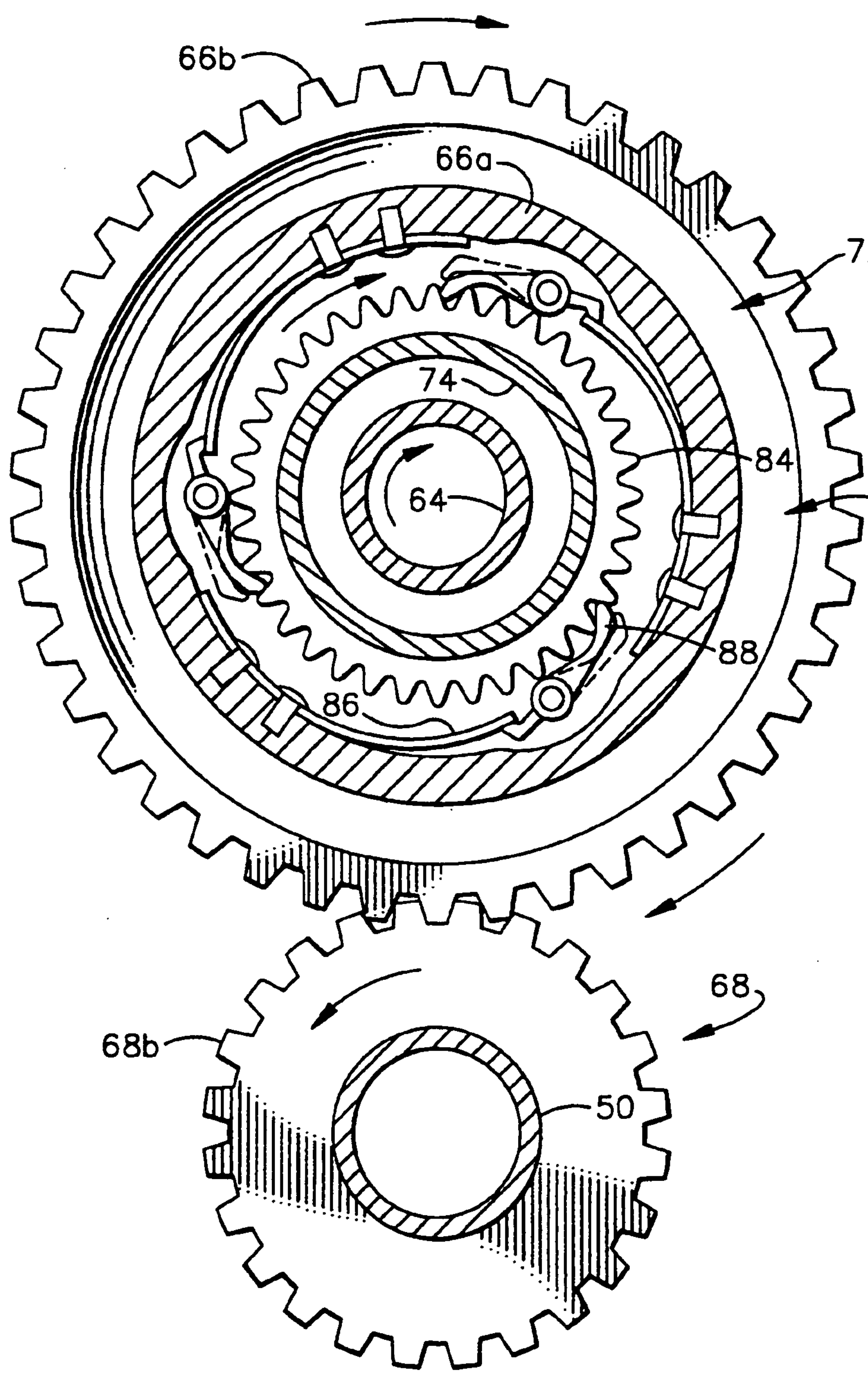

FIG. 5

AIR-START ASSEMBLY AND METHOD

The present invention relates generally to aircraft gas turbine engines, and, more specifically, to an assembly and method for air starting the engine during aircraft flight.

BACKGROUND OF THE INVENTION

Wide body commerical aircraft utilize turbofan gas turbine engines for powering the aircraft in flight. The turbofan engines includes a fan powered by a low pressure turbine (LPT) through a low pressure (LP) shaft, and a coaxial compressor powered by a high pressure turbine (HPT) through a high pressure (HP) shaft. The fan and LP shaft have a maximum rotational speed which is substantially less than the maximum rotational speed of the HP shaft for improving propulsion efficiency of the fan in powering the aircraft in flight.

In order to start the engine, a conventional air-driven starter is selectively operatively joined to the HP shaft through a suitable gearbox and is effective for rotating the HP shaft to a suitable speed of about 17% maximum RPM, so that the compressor can provide suitable compressed air to the combustor, which is then mixed with fuel and ignited for generating the combustion gases which power both the HPT and the LPT. The air starter is then suitably disconnected from the HP shaft once the engine is started and both the compressor and fan are being powered by the HPT and the LPT, respectively.

As aircraft turbofan engines become ever larger for producing higher levels of thrust, the compressor and HPT become larger and have larger rotational inertia which must be overcome by the starter for suitably rotating the HP shaft in order to start the engine. Accordingly, a correspondingly larger starter may be used to accelerate the HP shaft during start-up within an acceptable time interval, but, this increases installed weight of the engine in the aircraft and requires a suitably larger auxiliary power unit (APU) to drive the starter.

Furthermore, in the event engine restarting is required during flight of the aircraft, the time interval required to effect engine starting becomes more important and should be as small as possible for obtaining prompt engine start. Prompt air starting is also desirable without the need for increasing the size of the conventional starter or APU.

SUMMARY OF THE INVENTION

A method and assembly are effective for air-starting an aircraft gas turbine engine having a fan powered by a low pressure turbine through a first shaft, and a compressor powered by a high pressure turbine through a second shaft disposed coaxially therewith. A gear train is selectively operatively joined between the first and second shafts by selectively engaging a first clutch for transmitting torque through the first clutch only in one direction from the first shaft to the second shaft when the fan is windmilling for driving the second shaft to allow an air-start of the gas turbine engine during flight. In a preferred embodiment, a second clutch is operatively joined to the gear train and is selectively engageable at speeds of the second shaft below a predetermined release speed, and disengageable at the release speed and above for disconnecting the air-start assembly once the engine has been started.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, in accordance with preferred and exemplary embodiments, together with further objects and advantages thereof, is more particularly described in the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic, partly sectional view of an aircraft mounted turbofan gas turbine engine having an air-start assembly in accordance with one embodiment of the present invention.

FIG. 2 is an axial, partly sectional view of the air-start assembly illustrated in FIG. 1 disposed between the low pressure and high pressure shafts of the engine in accordance with one embodiment of the present invention.

FIG. 3 is a partly sectional view of selected components of the air-start assembly illustrated in FIG. 2 taken generally along line 3—3.

FIG. 4 is a partly sectional view through selected components of the air-start assembly illustrated in FIG. 2 including a centrifugal clutch therein and taken along line 4—4.

FIG. 5 is a partly sectional view of a portion of the air-start assembly illustrated in FIG. 2 taken along line 5—5 for showing a portion of a sprag clutch therein.

DESCRIPTION OF THE PREFERRED EMBODIMENTS(S)

Illustrated schematically in FIG. 1 is a turbofan gas turbine engine 10 conventionally mounted below a wing 12 of an aircraft 14, only a portion of which is shown. The engine 10 includes a conventional fan 16 having a plurality of circumferentially spaced apart fan blades powered by a conventional first, or low pressure turbine (LPT) 18 through a first, or low pressure (LP) shaft 20 extending therebetween. A conventional axial-flow compressor 22 is powered by a conventional second, or high pressure turbine (HPT) 24 through a second, or high pressure (HP) shaft 26 extending therebetween which is disposed coaxially around the first shaft 20. A conventional annular combustor 28 is disposed concentrically around the second shaft 26 and the first shaft 20, all coaxially about a longitudinal centerline axis 30 of the engine 10. The combustor 28 includes conventional fuel injectors 32 which selectively receive fuel from a conventional control unit 34.

The engine 10 receives amblent air 36 through the fan 16 with an outer portion of the air 36 providing thrust for powering the aircraft 14 in flight, and an inner portion of which is channeled to the compressor 22 wherein it is further compressed. The compressed air is then conventionally channeled to the combustor 28 wherein it is mixed with fuel from the injectors 32 and ignited by a conventional igniter 38 controlled by the control unit 34 for generating combustion gases 40 which flow in turn through the HPT 24 and the LPT 18 for powering the compressor 22 and the fan 16, respectively.

In order to conventionally start the engine on the ground or restart the engines 10 in the air, a conventional air-powered starter 42 is provided and receives compressed air from a conventional auxiliary power unit (APU) which is not shown. The starter 42 is joined to a conventional accessory gearbox 44 which is conventionally operatively joined to a transfer gearbox 46 through a suitable shaft 48. Extending from the transfer gearbox 46 is a conventional starter shaft 50, more commonly referred to as a power takeoff (PTO) shaft since

it is used for both starting the engine and for receiving power to drive the accessory gear box 44 and the several conventional accessory component joined thereto (not shown). Disposed at the distal end of the starter shaft 50 is a conventional bevel gear 52 operatively joined in engagement with a conventional HP shaft gear 54 disposed at one end of the second shaft 26 and coaxially about the centerline axis 30.

In order to conventionally start the engine 10, the starter 42 is provided with compressed air for turning its turbine therein which in turn rotates the shaft 48 and the starter 50, with the beveled gear 52 rotating the HP shaft gear 54 to drive the second shaft 26 at a suitable RPM of about 17% of its maximum speed, for example. The compressor 22 then compresses the air 36 which is discharged into the combustor 28 and mixed with fuel from the injectors 32, ignited by the igniter 38 to generate the self-sustaining combustion gases 40.

The engine 10 illustrated in FIG. 1 is representative of variously sized turbofan engines including relatively large engines wherein the compressor 22, HPT 24, and the second shaft 26 have a relatively high rotational inertia which must be suitably overcome for accelerating the second shaft 20 to a suitable speed for starting the engine.

In order to assist or supplant the conventional starter 42, an air-start assist assembly 56 in accordance with one embodiment of the invention is provided between the first shaft 20 and the second shaft 26, and is effective for starting the engine 10 solely during aircraft flight using power from the air 36 entering the fan 16.

More specifically, an improved method of air-starting the engine 10 includes the steps of:

windmilling the fan 16 to rotate the first shaft 20 joined thereto in the event of a flame-out of the combustor 28 which interrupts the generation of the combustion gases 40;

selectively joining the first shaft 20 to the second shaft 26 through a gear train 58 shown schematically in dashed line in FIG. 1, with the gear train 58 having a speed ratio greater than 1.0 for rotating the second shaft 26 by the windmilling of the fan 16;

starting the engine 10 by providing fuel through the fuel injectors 32 to mix with the compressed air provided by the compressor 22 into the combustor 28 and ignited by the igniter 38 for re-establishing the combustion gases 40; and

disconnecting the first shaft 20 from the second shaft 26 after the engine 10 has been started.

In this way, energy from the windmilling fan 16 may be used temporarily during aircraft flight for rotating the second shaft 26 to start the engine 10. And, once the engine 10 has been started, the first and second shafts 20 and 26 are disconnected from each other for allowing normal operation of the engine 10 with the second shaft 26 rotating substantially faster than the first shaft 20. For example, the first shaft 20 has a maximum rotational speed of about 2,000 RPM, and the second shaft 26 has a maximum rotational speed of about 10,000 RPM. Although the air-start assembly 56 may be used for temporarily joining together the first and second shafts 20 and 26 for airstarting, the two shafts must be disconnected from each other for allowing normal operation of the engine 10 and independent rotation of the two shafts 20, 26 in a conventional manner.

The air-start assembly 56 in accordance with a preferred and exemplary embodiment is illustrated in more particularity in FIG. 2. The gear train 58 may take any suitable configuration for providing a suitable speed increasing speed ratio greater than 1.0 from the first shaft 20 to the second shaft 26 for effective air starting. For example, in a flame-out condition of the engine 10 in flight, both the first and second shafts 20 and 26 will decelerate to relatively low rotational speeds. However, the fan 16, as shown in FIG. 1, will be caused to windmill by the air 36 channeled therethrough due to the forward movement of the aircraft 14. The windmilling fan 16 will reach a minimum rotational speed of about 17%, for example, of its maximum speed which may be about 400 RPM. The second shaft 26 in an exemplary embodiment must be rotated to about 20% of its maximum speed, or about 2,000 RPM in this example. Accordingly, the required gear speed ratio of the gear train 58 should be greater than about 2,000/400, or about 5:1 for suitably increasing the speed of the second shaft 26 by the windmilling rotation of the first shaft 20.

In the exemplary embodiment illustrated in FIGS. 2 and 3, the gear train 58 includes a first gear 60 having a hub 60*a* operatively joined coaxially to the first shaft 20, and further has gear teeth 60*b*. In this exemplary embodiment, the first gear hub 60*a* is fixedly joined around the first shaft 20 through a conventional spline, for example, so that rotation of the first shaft 20 causes identical rotation of the first gear 60 about the centerline axis 30 (see FIG. 1). A second gear 62 in the conventional form of a bevel pinion gear similarly has a hub 62*a* operatively joined to an idle shaft 64 disposed obliquely to the first and second shafts 20, 26. The second gear 62 includes gear teeth 62*b* joined in an engagement with the first gear teeth 60*b* for transmitting torque therebetween.

The gear train 58 further includes in this exemplary embodiment a third gear 66 having a hub 66*a* operatively joined to the idle shaft 64, and further has gear teeth 66*b*. A fourth gear 68 in the form of a bevel pinion gear has a hub 68*a* operatively joined to the starter shaft 50, and further has gear teeth 68*b* joined in engagement with the third gear teeth 66*b* for transmitting torque therebetween.

The gear train 58 is, therefore, operatively joined to the conventional starter shaft 50 by the added fourth gear 68 joined thereto for in turn selectively rotating the bevel gear 52 and the HP shaft gear 54. The gears 52 and 54 are, accordingly, fifth and sixth gears, respectively, of the overall gear train 58 for providing a speed increase from the first shaft 20 to the second shaft 26.

In the exemplary embodiment illustrated in FIG. 2, the sixth gear 54 is disposed coaxially with the second shaft 26 about the centerline axis 30 (see FIG. 1) and includes a hub 54*a* operatively, or fixedly, joined to the second shaft 26 around its outer diameter, and further has gear teeth 54*b* joined in engagement with gear teeth 52*b* of the fifth gear 52. The fifth gear 52 has a hub 52*a* operatively, or fixedly, joined to the distal end of the starter shaft 50 for transmitting torque between the shaft 50 and the second shaft 26.

In order to allow normal operation of the engine 10 after it has been started, the gear train 58 is preferably selectively operatively joined between the first and second shafts 20 and 26 by a selectively engageable one-way first clutch 70 for transmitting torque through the first clutch 70 only in one direction from the first shaft 20 to the second shaft 26 when the fan 16 is windmilling for driving the second shaft 26 to allow an air-start of the engine 10 during flight. Furthermore, a second clutch 72 is preferably also operatively joined to

the gear train 58 and is selectively engageable at speeds of the second shaft 26 below a predetermined release speed, and is disengageable at the release speed and above.

In this way, the gear train 58 is effective for transmitting torque solely in one direction from the first shaft 20 to the second shaft 26, and only during an air-start of the engine 10 wherein the speed of the second shaft 26 is relatively low. Once the engine 10 has been started and the speed of the second shaft 26 increases to its normal range, the second clutch 72 disengages to prevent unneeded rotation of gears within the gear train 58 which wastes energy and leads to unnecessary wear thereof. And, the first clutch 70 prevents transmission of torque backward through the gear train 58 from the second shaft 26 to the first shaft 20.

The first and second clutches 70 and 72 may be positioned in the gear train 58 at various locations for effective operation. In the exemplary embodiment illustrated in FIG. 2, the fourth gear 68 is fixedly joined to the starter shaft 50 at its hub 68a in a conventional manner by being formed integrally therewith, and the second clutch 72 is operatively joined between the idle shaft 64 and the third gear hub 66a for selectively allowing torque transmission from the idle shaft 64 through the second clutch 72 to the third gear 66, and in turn to the fourth gear 68, at speeds of the second shaft 26 below the predetermined release speed. The second clutch 72 is also effective for preventing torque transmission backwardly from the third gear 66 to the idle shaft 64 at and above the release speed. For example, the release speed may be about 20% of the maximum speed of the second shaft 26 selected to ensure suitable rotational speed of the second shaft 26 for rotating the compressor 22 for generating suitable compressed air for the combustor 28 for allowing ignition and initiation of the combustion gases 40.

The first clutch 70 is preferably operatively joined between the third gear 66 and the first shaft 20 for transmitting torque only from the first shaft 20 to the third gear 66 and preventing torque transmission from the third gear 66 to the first shaft 20. The first clutch 70 may be disposed at any suitable junction between the first shaft 20 and the third gear 66, and in the exemplary embodiment illustrated in FIG. 2 is operatively joined between the third gear 66 and the idle shaft 64.

Although the first and second clutches 70 and 72 may take any conventional form which are selectively engageable and operable as above described, in the preferred embodiment illustrated in FIG. 2 the first clutch 70 is a conventional sprag clutch and the second clutch 72 is a conventional centrifugal clutch joined to a common tubular clutch shaft 74 for providing a compact overall arrangement of the gear train 58 and the clutches 70, 72. The clutch shaft 74 is disposed coaxially between the idle shaft 64 and the third gear hub 66a which is also tubular and generally coextensive therewith. The first clutch 70 is operatively joined radially between the outer circumference of the idle shaft 64 and the inner circumference of the clutch shaft 74. And the second clutch 72 is operatively joined radially between the outer circumference of the clutch shaft 74 and the inner circumference of the third gear hub 66a.

FIG. 4 illustrates in more particularity a portion of the first or sprag clutch 70 which is conventional in configuration and operation. The sprag clutch 70 includes a plurality of circumferentially spaced apart and pivotable sprags or dogs 76 extending radially between the outer circumference of the idle shaft 64 and the inner circumference of the clutch shaft 74. The sprags 76 are conventionally loosely mounted in tubular, radially outer and inner cages 78, 80 and are sandwiched axially between a pair of energizing springs 82 in conventional fashion. As shown in solid line in FIG. 4, during an air-start the idle shaft 64 is being rotated in the clockwise direction by the second gear 62 in turn from the first gear 60 joined to the first shaft 20 (see FIG. 2). This causes the sprags 76 to exert a wedge-like force between the idle shaft 64 and the clutch shaft 74 for transmitting torque in a clockwise direction from the idle shaft 64 to the clutch shaft 74. This torque transmission occurs solely with clockwise rotation of the idle shaft 64 relative to the clutch shaft 74 to ensure only one way transmission of torque from the first shaft 20 to the second shaft 26. In the event the clutch shaft 74 were to be caused to rotate clockwise relative to the idle shaft 64, the sprags 76 will be displaced to the position shown in dashed line in FIG. 4 which removes the wedge forces between the sprags 76 and the shafts 64, 74 and prevents backwards the transmission of torque from the clutch shaft 74 to the idle shaft 64.

The second, or centrifugal clutch 72 is illustrated in more particularity in FIG. 5. The centrifugal clutch 72 is also conventional in structure and operation and includes a plurality of clutch teeth 84 extending radially outwardly from a portion of the clutch shaft 74. A plurality of circumferentially spaced apart leaf springs 86 extend radially inwardly from the third gear hub 66a, and have proximal ends suitably fixedly joined thereto by bolts or rivets, for example. A plurality of circumferentially spaced apart conventional dogs 88 are conventionally pivotally joined to a suitable sidewall of the third gear hub 66a between the leaf springs 86 and clutch teeth 84. The distal ends of the springs 86 contact the respective proximal ends of the dogs 88 for biasing the distal ends of the dogs 88 in engagement with the clutch teeth 84 for transmitting torque between the clutch shaft 74 and the third gear 66 at speeds below the release speed. As shown in FIG. 5, when the clutch shaft 74 rotates in the clockwise direction, the teeth 84 engage the distal ends of the dogs 88 which in turn transmits torque through the dogs 88 into the third gear hub 66a for rotating the third gear 66 also in the clockwise direction. The third gear teeth 66b then rotate the fourth gear 68 in a counterclockwise direction as shown in FIG. 5 which in turn rotates the starter shaft 50 for rotating the fifth gear 52 and in turn the sixth gear 54 and second shaft 26 as illustrated in FIG. 2. As the speed of the third gear 66 increases, centrifugal force acting on the distal ends of the dogs 88 causes the dogs 88 to rotate in a clockwise direction shown in dashed line in FIG. 5 against the biasing force of the springs 86 which compresses the springs 86 radially outwardly to release the dogs 88 from the clutch teeth 84 at and above the predetermined release speed. In this way, when the second shaft 26 is operating above the release speed, the dogs 88 will be disengaged from the clutch teeth 84 for disengaging the second clutch 72.

Accordingly, in a normal start of the engine 10 such as on the ground, the original air starter 42 will operate to rotate the starter shaft 50 for rotating the second shaft 26. The centrifugal clutch 72 will be engaged up to the release speed, but the sprag clutch 70 will slip and prevent reverse torque through the gear train 58 from rotating the first shaft 20, and in turn the fan 18. Once the engine 10 is started and both the first and second

shafts 20 and 26 reach their normal operating speeds, the centrifugal clutch 72 will be disengaged by centrifugal force acting on the dogs 88, and the sprag clutch 70 will continue to slip so that no torque is transmitted from the first shaft 20 to the second shaft 26.

Under a normal engine shut-down, for example during flight, the second shaft 26 will coast down more quickly than the first shaft 20 causing the centrifugal clutch 72 to engage once the release speed is reached, which will have no effect since the sprag clutch 70 continues to slip and prevents reverse torque flow through the gear train 58 to the first shaft 20. However, once the speed of the clutch shaft 74 becomes less than or equal to about the speed of the idle shaft 64 during such coastdown, the sprags 76 will engage but only for transmitting torque from the idle shaft 64 to the clutch shaft 74 for air starting the engine 10 using the air-start assembly 56. The windmilling fan 16 will rotate the first gear 60 which in turn rotates the second gear 62 and idle shaft 64 for transmitting torque through the sprags 76 to the clutch shaft 74. The clutch shaft 74 will transmit torque through the dogs 88 to the third gear 66 and in turn to the fourth, fifth, and sixth gears 68, 52, and 54, respectively for rotating the second shaft 26 to allow the engine 10 to be air started.

As shown in FIGS. 2 and 3, the first gear 60 is a relatively large gear having the same center as the centerline axis 30, with the second gear 62 being substantially smaller compared thereto. This larger gear to small gear arrangement provides one speed increase ratio. The third gear 66 is also larger than the fourth gear 68 and provides another speed increase ratio. The conventionally sized fifth gear 52 is substantially smaller than the sixth gear 54 for providing a speed reduction. However, the speed increase from the first, second, third, and fourth gears 60, 62, 66, and 68 may be selected relative to the speed reduction of the fifth and sixth gears 52, 54 to provide an overall speed increase ratio substantially greater than 1.0, and about 5:1 in this exemplary embodiment since the second shaft 26 needs to be rotated at about five times the speed of the first shaft 20 when it is windmilling in flight. Of course, the particular speed ratios may be conventionally determined for each design application for providing effective air starting of the engine 10 when required.

By combining the air-start assist assembly 56 with the originally provided starter shaft 50 and bevel gear 52, the original air starter 42 may also be used during the air-start if desired. Accordingly, the additional energy provided by the air-start assembly 56 for starting the engine 10 during flight, allows the original air starter 42, and its APU, to remain relatively small for reducing weight and maintaining overall efficiency of the combination.

In an alternate embodiment for the invention, the first and second clutches 70 and 72 may be located at different locations between the first and second shafts 20, 26 and relative to the gears of the gear train 58 if desired. And, as shown in FIG. 2, the air-start assembly 56 includes a suitable stationary housing 90 from which the gears and shafts described above are conventionally mounted in roller and/or ball bearings. The housing 90 may be mounted to the original frame 92 supporting the starter shaft 50, or may be, alternatively, mounted to the conventional bearing cone 94 which supports the first shaft 20.

While there have been described herein what are considered to be preferred and exemplary embodiments of the present invention, other modifications of the invention shall be apparent to those skilled in the art from the teachings herein, and it is, therefore, desired to be secured in the appended claims all such modifications as fall within the true spirit and scope of the invention.

Accordingly, what is desired to be secured by Letters Patent of the United States is the invention as defined and differentiated in the following claims:

We claim:

1. An air-start assembly for an aircraft gas turbine engine having a fan powered by a low pressure turbine through a first shaft, and a compressor powered by a high pressure turbine through a second shaft disposed coaxially around said first shaft comprising:

a gear train selectively operatively joined between said first and second shafts by a selectively engageable first clutch for transmitting torque through said first clutch only in one direction from said first shaft to said second shaft when said fan is windmilling for driving said second shaft to allow an air-start of the gas turbine engipe during flight; and

a second clutch operatively joined to said gear train and selectively engageable at speeds of said second shaft below a predetermined release speed, and disengageable at said release speed and above;

wherein said first clutch comprises a sprag clutch and said second clutch comprises a centrifugal clutch;

wherein said gear train has a speed ratio greater than 1.0 from said first shaft to said second shaft;

wherein said gear train comprises:

a first gear having a hub operatively joined coaxially to said first shaft, and further having gear teeth;

a second gear having a hub operatively joined to an idle shaft, and having teeth joined in engagement with said first gear teeth for transmitting torque therebetween;

a third gear having a hub operatively joined to said idle shaft, and further having gear teeth;

a fourth gear having a hub operatively joined to a starter shaft, and further having gear teeth joined in engagement with said third gear teeth;

a fifth gear having a hub operatively joined to said starter shaft, and further having gear teeth; and

a sixth gear having a hub operatively joined to said second shaft, and further having gear teeth joined in engagement with said fifth gear teeth.

2. An air-start assembly for an aircraft gas turbine engine having a fan powered by a low pressure turbine through a first shaft, and a compressor powered by a high pressure turbine through a second shaft disposed coaxially around said first shaft comprising;

a gear train selectively operatively joined between said first and second shafts by a selectively engageable first clutch for transmitting torque through said first clutch only in one direction from said first shaft to said second when said fan is windmilling for driving said second shaft to allow an air-start of the gas turbine engine during flight; and

a second clutch operatively joined to said gear train and selectively engageable at speeds of said second shaft below a predetermined release speed, and disengageable at said release speed and above;

wherein said gear train has a speed ratio greater than 1.0 from said first shaft to said second shaft;

wherein said gear train comprises;

a first gear having a hub operatively joined coaxially to said first shaft, and further having gear teeth;

a second gear having a hub operatively joined to an idle shaft and having teeth joined in engagement with said first gear teeth for transmitting torque therebetween;

a third gear having a hub operatively joined to said idle shaft, and further having gear teeth;

a fourth gear having a hub operatively joined to a starter shaft, and further having gear teeth joined in engagement with said third gear teeth;

a fifth gear having a hub operatively joined to said starter shaft, and further having gear teeth; and

a sixth gear having a hub operatively joined to said second shaft, and further having gear teeth joined in engagement with said fifth gear teeth;

wherein said second clutch is operatively joined between said idle shaft and said third gear hub for selectively allowing torque transmission from said idle shaft through said second clutch to said third gear below said release speed of said second shaft, and for preventing torque transmission from said third gear to said idle shaft at and above said release speed.

3. An assembly according to claim 5 wherein said first clutch is operatively joined between said third gear and said first shaft for transmitting torque only from said first shaft to said third gear, and for preventing torque transmission from said third gear to said first shaft.

4. An assembly according to claim 3 wherein said first clutch is operatively joined between said third gear and said idle shaft.

5. An assembly according to claim 4 further including a tubular clutch shaft disposed coaxially between said idle shaft and said third gear hub; and wherein said first clutch is operatively joined between said idle shaft and said clutch shaft, and said second clutch is operatively joined between said clutch shaft and said third gear hub.

6. An assembly according to claim 5 wherein said first clutch is a sprag clutch having a plurality of circumferentially spaced apart pivotable sprags extending radially between said idle shaft and said clutch shaft.

7. An assembly according to claim 6 wherein said second clutch is a centrifugal clutch having:

a plurality of clutch teeth extending radially outwardly from said clutch shaft;

a plurality of springs extending radially inwardly from said third gear hub;

a plurality of circumferentially spaced apart dogs pivotally joined to said third gear hub and disposed between said springs and said clutch teeth; and

said springs being configured to bias said dogs in engagement with said clutch teeth for transmitting torque between said clutch shaft and said third gear below said release speed, and being compressible by centrifugal force from said dogs to release said dogs from said clutch teeth at and above said release speed.

* * * * *

United States Patent [19]
Wilde et al.

[11] 4,248,041
[45] Feb. 3, 1981

[54] GAS TURBINE ENGINE POWER PLANT

[75] Inventors: Geoffrey L. Wilde, Turnditch; Maurice I. Taylor, Allestree; Geoffrey P. Medland, Castle Donington, all of England

[73] Assignee: Rolls-Royce Limited, London, England

[21] Appl. No.: 957,033

[22] Filed: Oct. 27, 1978

[30] Foreign Application Priority Data

Dec. 3, 1977 [GB] United Kingdom 50457/77

[51] Int. Cl.³ F02K 1/10; F02K 3/06
[52] U.S. Cl. .... 60/226 R; 60/229; 60/230; 60/224; 244/12.5; 244/23 D
[58] Field of Search .... 60/224, 226 R, 226 A, 60/226 B, 229, 230, 232, 262, 263; 244/12.3, 12.4, 12.5, 23 D, 52

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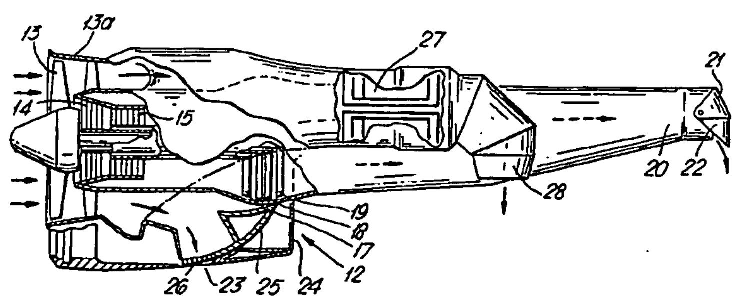
Primary Examiner—Stephen C. Bentley
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] ABSTRACT

A V.S.T.O.L. gas turbine power plant includes a main gas turbine engine having an exhaust gas propulsion nozzle and a fan arranged within a fan duct, which duct terminates in two nozzles such that a portion of the fan air may be directed vertically downwards or horizontally, the remaining portion of the fan air acts as a working fluid in one or more further auxiliary gas turbine engines each engine including a vectorable exhaust nozzle.

5 Claims, 4 Drawing Figures



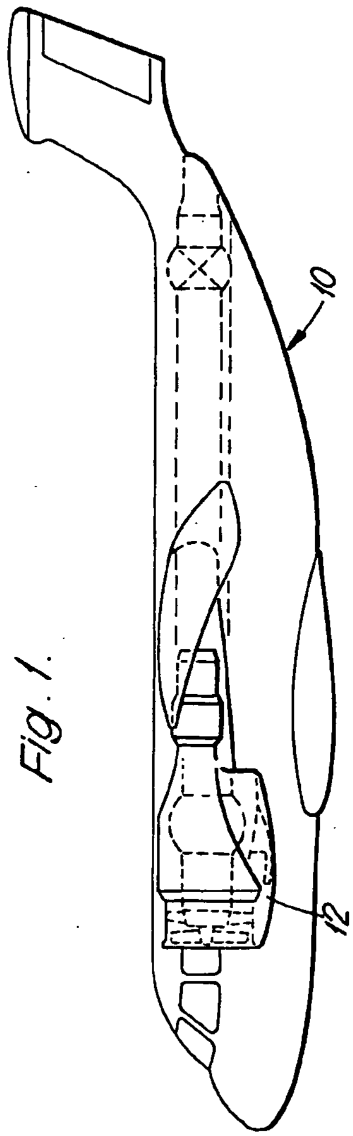


Fig. 1.

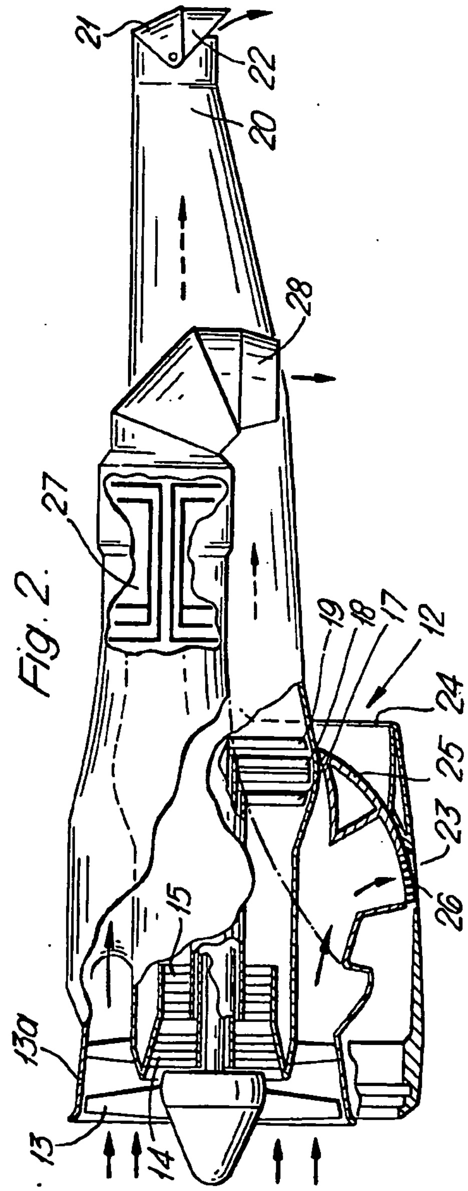


Fig. 2.

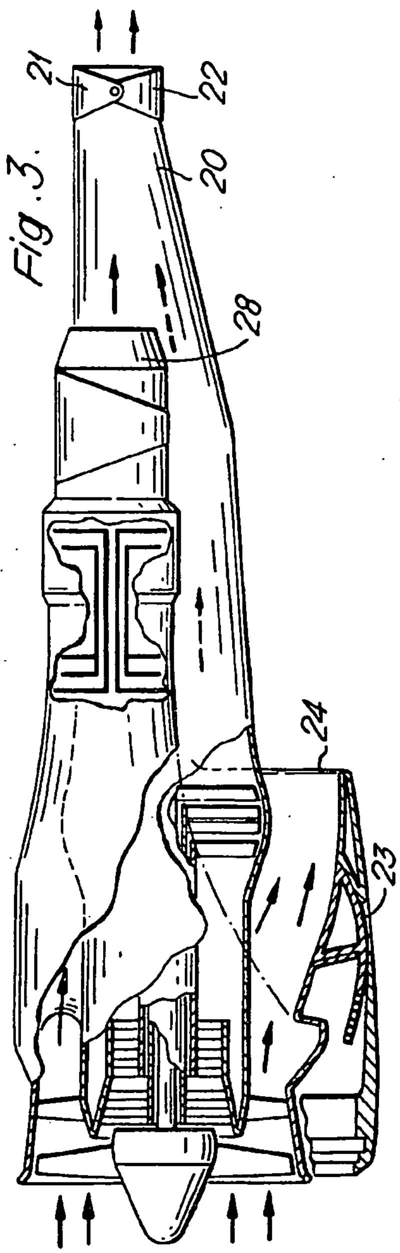


Fig. 3.

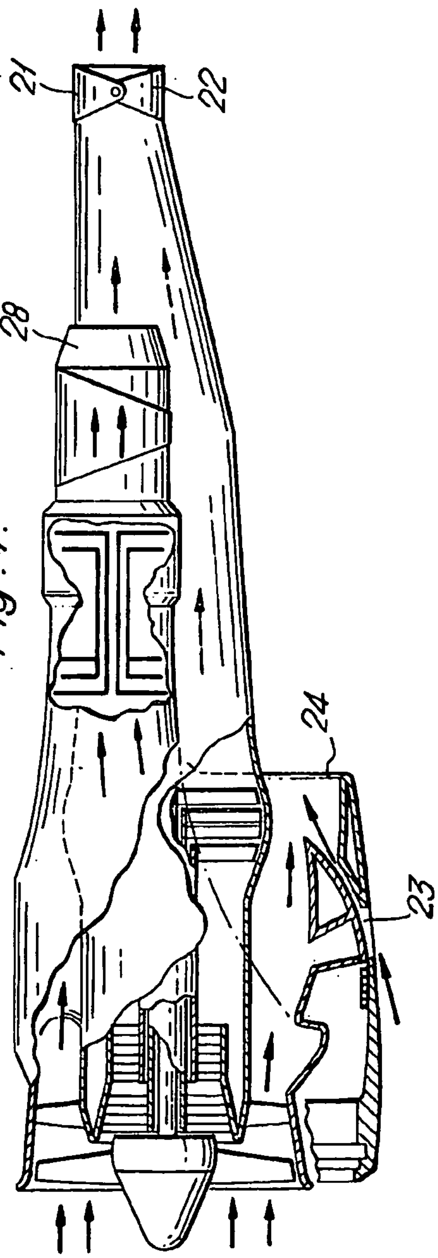


Fig. 4.

GAS TURBINE ENGINE POWER PLANT

This invention relates to gas turbine engine power plants and in particular to gas turbine engine power plants suitable for use in Vertical Take Off and Landing, or Short Take Off and Landing (V.T.O.L. or S.T.O.L.) type aircraft.

It is well known to provide such aircraft with a single gas turbine engine having a plurality of pivotal exhaust nozzles by means of which the direction of thrust produced by the engine may be varied. The aircraft can either be propelled forward in conventional flight with the nozzles discharging rearwards, or it can hover, or move vertically with the nozzles discharging downwards. The nozzles may be adjusted such as to provide both a degree of vertical lift and horizontal propulsion for transition between conventional forward flight and hover.

The best known type of such engines is provided with four pivotal exhaust nozzles the downstream two of which are supplied with hot exhaust gas, and the upstream two of which are supplied with relatively cool by-pass air.

Many proposals have been made for increasing the thrust of this type of engine all of which suffer from disadvantages. Such a type of engine has a low by-pass ratio and consideration has been given to either "scaling up" such an engine or alternatively increasing its by-pass ratio. This however results in the forward nozzles and associated pipework having to be excessively large to accomodate the increased flow of low pressure by-pass air.

Alternatively it has been proposed that the thrust from the two forward nozzles could be increased by burning additional fuel in the by-pass air passing to the nozzles (this is commonly known as reheat or plenum chamber burning). This suffers two main disadvantages, firstly the combustion of the fuel in the relatively low pressure by-pass air is inefficient and leads to high specific fuel consumption. Secondly uprating the thrust of the foremost nozzles leads to thrust balancing problems. For an engine of this type to function satisfactorily in an airframe, it is necessary to ensure that the resultant upthrust of all the nozzles pass through the centre of gravity of the engine/airframe combination when the nozzles are directed downwards. Therefore unless the foremost nozzles are continuously provided with reheat the thrust balance is not maintained.

A further alternative is to provide a gas turbine power plant comprising a main engine having a propulsion nozzles or nozzles and at least one auxiliary engine which is supplied with air from the main engine, the auxiliary engine being also provided with one or more vectorable propulsion nozzles.

All these types of engine suffer disadvantages in that they all have a relatively large frontal area which obviously increases aircraft drag. A further disadvantage is that as has previously been stated the engine thrust vector used in supporting or raising and lowering the aircraft vetically must be arranged as close to the aircraft centre of gravity as possible. This has usually resulted in the addition of weight to the aircraft nose or tail structure to achieve the necessary balance, obviously any weight increase in an aircraft is particularly undesirable.

An object of the present invention is to provide a gas turbine power plant suitable for a V.T.O.L. or S.T.O.L. aircraft in which the aforementioned disadvantages are substantially eliminated.

According to the present invention a V.S.T.O.L. gas turbine power plant comprises a main gas turbine core engine having an exhaust gas propulsion nozzle and a fan arranged within a fan duct, the fan duct including two exhaust nozzles by means of which a portion of the fan efflux may be ejected from the duct, a further portion of the fan efflux acting as a working fluid for at least one auxiliary gas turbine engine each at least one auxiliary engine having at least one vectorable exhaust nozzle.

Preferably the two fan nozzles are provided such that one ejects fan air in a vertically downward direction and the other ejects fan air in a horizontal direction.

Preferably the two fan nozzles are provided with a common slidable flap which is adapted to close off one or the other of the nozzles, and the flap includes a plurality of flow directing vanes whereby the fan efflux is directed vertically downwards from one said nozzle when this is in the operative condition.

For better understanding of the invention an embodiment thereof will now be more particularly described by way of example only and with reference to the accompanying drawings in which;

FIG. 1 shows a diagrammatic side view of a V.S.T.O.L. transport type aircraft,

FIG. 2 shows a diagrammatic side view of a power plant in the vertical take off mode of operation suitable for the aircraft shown diagrammatically at FIG. 1.

FIG. 3 shows a diagrammatic side view of the same power plant as that shown in FIG. 2 but in the normal cruise mode of operation,

FIG. 4 shows a diagrammatic side view of the same power plant in the high speed cruise mode of operation.

Referring to FIG. 1 of the drawings an aircraft is shown diagrammatically at 10 and includes a portion of one power plant 12. It is envisaged that this aircraft would be propelled by two such power plants are being arranged on either side of the aircraft fuselage in pods.

FIG. 2 of the drawings shows an enlarged diagrammatic view of the power plant 12 which comprises a main core engine including in flow series a fan 13 situated within a fan duct 13*a*, an intermediate pressure compressor 14, a high pressure compressor 15, combustion equipment (not shown), a high pressure turbine 17, an intermediate pressure turbine 18, a low pressure turbine 19, the core engine terminating in a hot gas exhaust nozzle 20. The hot gas exhaust nozzle 20 also includes thrust reverser buckets 21 and 22.

The fan duct 13*a* terminates in two exhaust nozzles 23 and 24 each of which may be selectively closed off by means of a slidable flap 25 which is displaced between its respective locations by means not shown in the drawings. The slidable flap 25 also includes adjacent one end a plurality of flow diverting vanes 26 whereby the thrust from the nozzle 23 is directed vertically downwards.

Also arranged within a portion of the fan duct are two auxiliary engines one of which is shown at 27 the other being arranged in a similar location on the opposite side of the core engine 12. Each auxiliary engine which is shown diagrammatically at 27 comprises a gas turbine engine which in this particular embodiment is a two shaft engine. However it is envisaged that the auxiliary engines could in fact take the form of a one or three shaft engine if desired.

Each auxiliary engine 27 is supplied with pressurised fan air as a working fluid, and each engine terminates in a vectorable exhaust nozzle 28.

FIG. 2 of the drawings shows the power plant 12 in the vertical take off mode of operation and in this configuration the nozzle 24 is closed off by the flap 25 and approximately 30% of the fan air is directed through the cascade of flow directing vanes 26 and nozzle 23. The remaining 70% of the fan air is consumed by the auxiliary engines 27 such that they develop maximum power and their respective nozzles 28 are directed vertically downwards. The thrust reverser buckets 21 and 22 are arranged such as to direct the hot exhaust gas flow from the main core engine nozzle 20 vertically downwards. Transition from vertical flight to forward flight is achieved by vectoring the thrust rearwards from the nozzles 23, 24, 28 and the nozzle 20.

FIG. 3 shows a diagrammatic view of the power plant 12 in the normal or economical cruise condition. In this mode of operation the nozzle 23 is closed off by the flap 25 such that only the horizontal nozzle 24 is operative. The auxiliary engine nozzles 28 are directed horizontally, and the thrust reverser buckets 21 and 22 are positioned such as to provide an uninterrupted horizontal flow through the nozzle 20. In this configuration the two auxiliary engines 27 are maintained at flight idling speed to avoid base drag from their respective nozzle 28. The majority of the fan air in this instance is directed through the nozzle 24.

FIG. 4 shows a diagrammatic side view of the power plant 12 in the acceleration or high speed cruise condition. In this mode of operation the auxiliary engines 27 are run at high speed and the nozzle 24 is reduced in area.

It will be appreciated that by use of a power plant made in accordance with the present invention it is possible to provide an aircraft with the capabilities of both vertical take-off and landing and also economical cruise or alternatively high speed capability.

We claim:

1. A V/STOL gas turbine power plant for aircraft comprising:

a main gas turbine core engine having an air intake and an exhaust gas propulsion nozzle;

at least one auxiliary gas turbine engine having an air intake and a vectorable exhaust gas nozzle;

a fan;

a fan duct surrounding said fan and in continuous open communication with both the air intake of said main gas turbine core engine and the air intake of said at least one auxiliary gas turbine engine for continuously supplying a portion of the fan air thereto, said fan duct including two fan air exhaust nozzles for ejecting another portion of the fan air from the fan duct, one of said fan air exhaust nozzles ejecting fan air in a vertically downward direction and the other of said fan air exhaust nozzles ejecting fan air in a horizontal direction;

and valve means for selectively closing one of said two fan air exhaust nozzles while at least partially opening the other of said two fan air exhaust nozzles.

2. A V/STOL gas turbine power plant as claimed in claim 1 in which said valve means includes a common slideable flap arranged to close at least one of said two fan air exhaust nozzles while at least partially opening the other of said two fan air exhaust nozzles.

3. A V/STOL gas turbine power plant as claimed in claim 2 wherein said slideable flap includes a plurality of flow directing vanes for directing the fan air efflux through the one of said two fan air exhaust nozzles which is arranged for ejecting fan air downwardly.

4. A V/STOL gas turbine power plant as claimed in claims 1, 2 or 3 in which said exhaust gas propulsion nozzle of said main gas turbine core engine is vectorable.

5. A V/STOL gas turbine power plant as claimed in claims 1, 2 or 3 in which said valve means has three positions of operation, a first position wherein said one fan air exhaust nozzle for ejecting fan air in a downward direction is open and said other fan air exhaust nozzle for ejecting fan air in a horizontal direction is closed, a second position wherein said fan air exhaust nozzle for ejecting fan air in a downward direction is closed and said other fan air exhaust nozzle for ejecting fan air in a horizontal direction is fully open, and a third position wherein in said one fan air exhaust nozzle for ejecting fan air in a downward direction is closed and said other fan air exhaust nozzle for ejecting fan air in a horizontal direction is partially open.

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